Signal-to-Noise Ratio (SNR) - Detailed BS Level Lecture Notes

1. Introduction
Signal-to-Noise Ratio (SNR) is a measure of signal quality. It compares the useful signal level to the background noise level in a system. It is widely used in electronics, communication systems, analytical chemistry, and instrumentation.

2. Mathematical Definition
SNR = Signal Power (S) / Noise Power (N)
SNR(dB) = 10 log10 (S/N)

If voltage values are given:
SNR(dB) = 20 log10 (Vs/Vn)

3. Physical Meaning
• High SNR → Signal dominates over noise → Accurate measurement
• Low SNR → Noise dominates → Distorted or unreliable signal
• SNR = 0 dB → Signal power equals noise power

4. Types of Noise
• Thermal (Johnson) Noise – Due to random motion of electrons
• Shot Noise – Due to discrete charge flow
• Flicker (1/f) Noise – Important at low frequencies
• Environmental Noise – External electromagnetic interference

5. Numerical Examples
Example 1:
Signal Power = 100 W
Noise Power = 1 W
SNR = 100/1 = 100
SNR(dB) = 10 log10(100) = 20 dB

Example 2:
Signal Voltage = 5 V
Noise Voltage = 0.5 V
SNR(dB) = 20 log10(5/0.5) = 20 log10(10) = 20 dB

6. Graphical Concept (Explanation)
In a signal spectrum graph, the signal appears as a sharp peak while noise appears as small random fluctuations around the baseline. Higher peak height relative to baseline indicates higher SNR.

7. Importance in Analytical Chemistry
• Limit of Detection (LOD): SNR ≥ 3
• Limit of Quantification (LOQ): SNR ≥ 10
Higher SNR improves sensitivity and precision of instruments.

8. Methods to Improve SNR
• Increase signal strength
• Reduce temperature (to reduce thermal noise)
• Proper shielding and grounding
• Filtering unwanted frequencies

• Signal averaging techniques

9. Applications
• Spectroscopy
• Chromatography
• Audio systems
• Wireless communication
• Medical imaging

Conclusion
Signal-to-Noise Ratio is a critical parameter that determines system performance. A higher SNR ensures better accuracy, reliability, and quality in scientific measurements and communication systems.